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THE TENTATIVE NORMAL DIURNAL HEIGHT CHANGE OF THE 700-MILLIBAR SURFACE OVER THE UNITED STATES AND ADJACENT AREAS

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INTRODUCTION

In the course of constructing prognostic 700-millibar contour charts, there is a need for information concerning the normal diurnal height change of that surface during the 12 hours between the two daily radiosonde observations. The observed height changes are corrected by subtracting the diurnal height change. The heights forecast on a 12- or 36-hour prognostic chart also should be corrected by adding the diurnal height change. This need for values of the normal diurnal height change is particularly great in working with comparatively weak summer weather patterns where for a given 12-hour period the diurnal height change is an appreciable percentage of the height change associated with the movement of weather systems.

To fill the need, computation of the normals was undertaken. Limitations in data prevented basing computations on a long record; in fact, valid data were available for only 2 years. Nevertheless, by applying smoothing techniques to those 2 years of data, it was possible to obtain tentative normals approximating long period averages.

The results of the computations are presented here in 12 monthly charts of the tentative normal 700-mb. height change from 0300 GMT to 1500 GMT, in feet per 12 hours. Diurnal 700-mb. height change charts similar to these have been utilized by Weather Bureau-Air Force-Navy Analysis Center personnel since early in 1948. The accuracy of the tentative normals has been found adequate for routine prognostication work. This fact justifies publishing the charts to satisfy immediate demands for quantitative information about the diurnal variation in height of the 700-mb. surface. The charts are intended to serve until the time when accurate data are available for a long enough period (perhaps 10 years) to permit construction of a permanent set of charts.

To emphasize the tentative nature of the charts and to caution against their indiscriminate use, the following paragraphs describe the limitations of the data, the methods of computing the normals, and some of the factors influencing their reliability.

DATA LIMITATIONS

As already mentioned, limitations in data prevented computing long period averages. Although twice-daily radiosonde observations have been available for the United States since 1941, much of the record could not be used because of errors in computed heights of pressure surfaces resulting from errors in the temperatures transmitted by the radiosonde instrument. In particular, for daytime radiosonde flights, computed heights are too high if the temperature measuring element is warmed appreciably by solar radiation. Thus, diurnal height changes computed from such data are in error by the value of the *virtual* diurnal height changes, that is, that part of the diurnal height change resulting from the difference between the radiational temperature errors for the two times of observation.

Although radiosondes with negligible radiational temperature errors have been used in the United States for several years, few stations used these instruments exclusively before January 1947. For this reason, it was undesirable in this investigation to use data for previous years and only the data for the 2-year period January 1947 through December 1948 were used.

As a direct step toward computing the normal diurnal values, an attempt involving a great amount of labor was made to use original station radiosonde records. However, monthly means of such records were biased toward high values unless recomputed after individual daily values, missing as a result of bad weather (and therefore generally low values) had been estimated. In addition, longer breaks in station records resulting from equipment shortages and other causes were found to be very difficult to handle. For these reasons, it was necessary to look elsewhere for suitable twice-daily values of the heights of the 700-mb. surface.

The data for the period January 1947 through December 1948 found suitable for processing were the heights of the 700-mb. surface taken at selected latitude and longitude intersections from maps analyzed twice daily by the Extended Forecast Section of the Weather Bureau. The grid of selected points consisted of intersections for every

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5 degrees of latitude and longitude over and near the United States and intersections for every 5 degrees of latitude and alternating 10-degree intervals of longitude elsewhere. These data recorded on punched cards were made available by the Machine Tabulation Unit of the Weather Bureau.

For areas adjacent to the continental limits of the United States, the analyses from which the diurnal values are derived, are based in part on sparse, irregular data and on heights extrapolated from surface data. However, there is sufficient consistency in the diurnals computed over these areas to justify including them in the charts published here. But, to indicate that the reliability of the diurnals over these areas is not on a par with those over the United States, the isopleths are dashed.

COMPUTING THE MONTHLY MEAN VALUES

After the selection of data for processing, the next step was to compute the monthly mean of the diurnal height change for each intersection described in the preceding section. The 12-hour diurnal height change at a point was found by averaging two 0300 GMT 700-mb. height values at 24-hour intervals and subtracting this average 0300 GMT height from the height of the surface given by the intermediate 1500 GMT analysis. Then, the monthly mean of the 12-hour changes was determined by the formula:

$$\frac{\Sigma h}{n}-\frac{2\Sigma H-H_c+H_f}{2n} \text{ or } \frac{\Sigma h-\Sigma H}{n}+\frac{H_c-H_f}{2n}$$

where Σh=the monthly sum of the daily 1500 GMT 700-mb. heights,
ΣH=the monthly sum of the daily 0300 GMT 700-mb. heights,
H_c=the height of the 700-mb. surface at 0300 GMT on the first day of the current month,
H_f=the height of the 700-mb. surface at 0300 GMT on the first day of the following month,
n=the number of days in the current month.

The term $\frac{\Sigma h-\Sigma H}{n}$ is the monthly mean difference between the twice daily observations. The remaining expression, $\frac{H_c-H_f}{2n}$ is a correction term which tends to eliminate the seasonal trend of the height of the 700-mb. surface and also the effect of any nonseasonal variation from generally low values over a particular area at the beginning of a month to generally high values at the end of the month, or high values at the beginning and low at the end. The averaging process must be depended on to minimize the effect of nonrepresentative values of the diurnal height change which occur with the passage of weather systems.

For use in determining the monthly means, monthly values of the quantity $2\Sigma h-2\Sigma H+H_c-H_f$ for the period January 1947 through December 1948 were computed by the Machine Tabulation Unit. Division of these monthly data by 2n gave the monthly mean-diurnal height difference between the 12-hourly observations.

The field of mean values obtained was somewhat irregular in certain parts of the country and to a larger extent outside the United States where 700-mb. analyses were based on data from widely scattered stations. Doubtless these irregularities came about because the period covered by the data is a short one on which to base normal values. In contrast to this short period, for example, a 10-year record was used in computing the normal surface diurnal pressure change for the United States [1]. To eliminate these irregularities, a smoothing process now to be described was used.

SMOOTHING THE MONTHLY MEAN VALUES

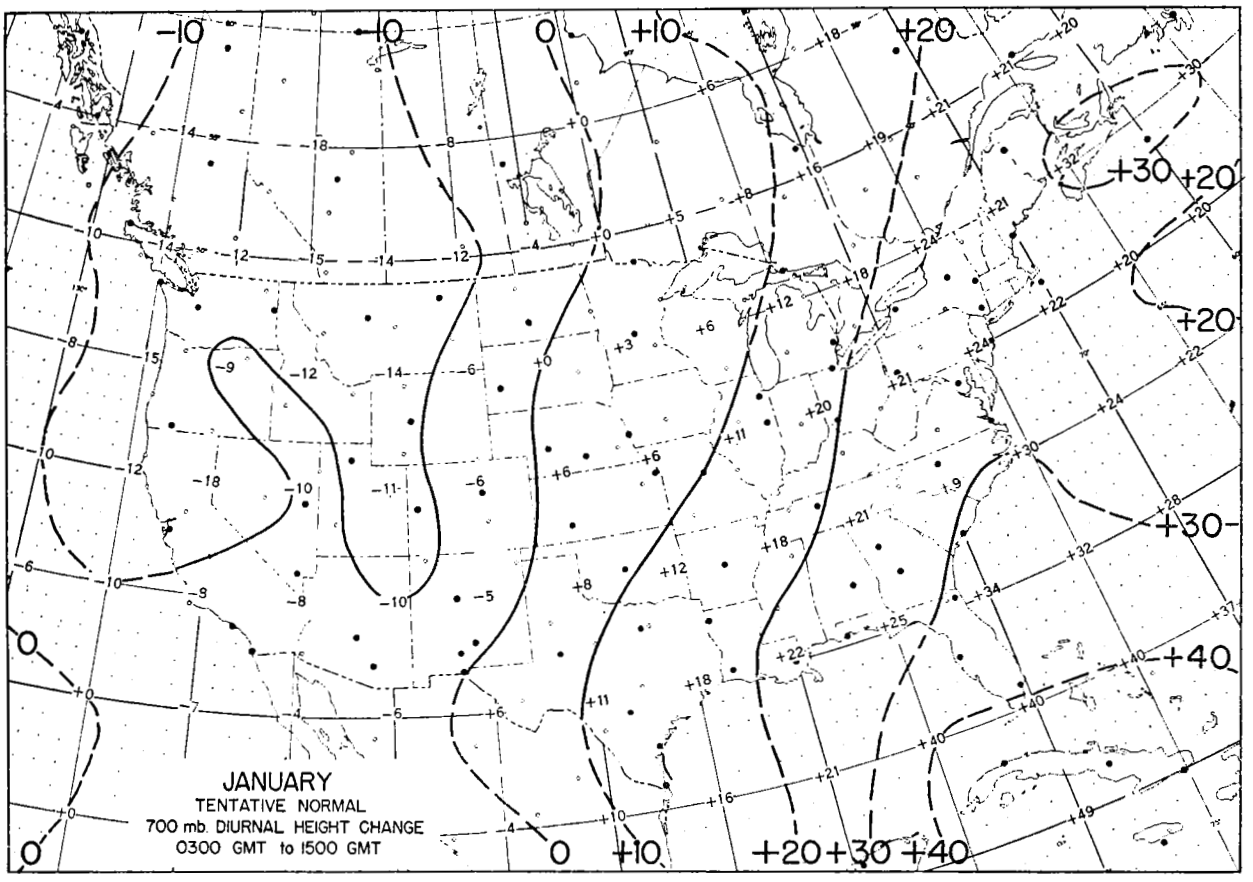
In the smoothing process, it was necessary to plot a separate graph of the monthly mean values for each latitude and longitude intersection. The abscissa of the graph is the month of the year and the ordinate, the value of the monthly mean diurnal height change. At intersections where irregularities made it necessary, curves smoothing the month-to-month trend of the diurnal change were drawn on these graphs to satisfy the plotted data as well as possible but at the same time to account for the similarity each curve should have to curves at neighboring intersections, and for the regularity of month-to-month variation that would be compatible with factors causing the variation.

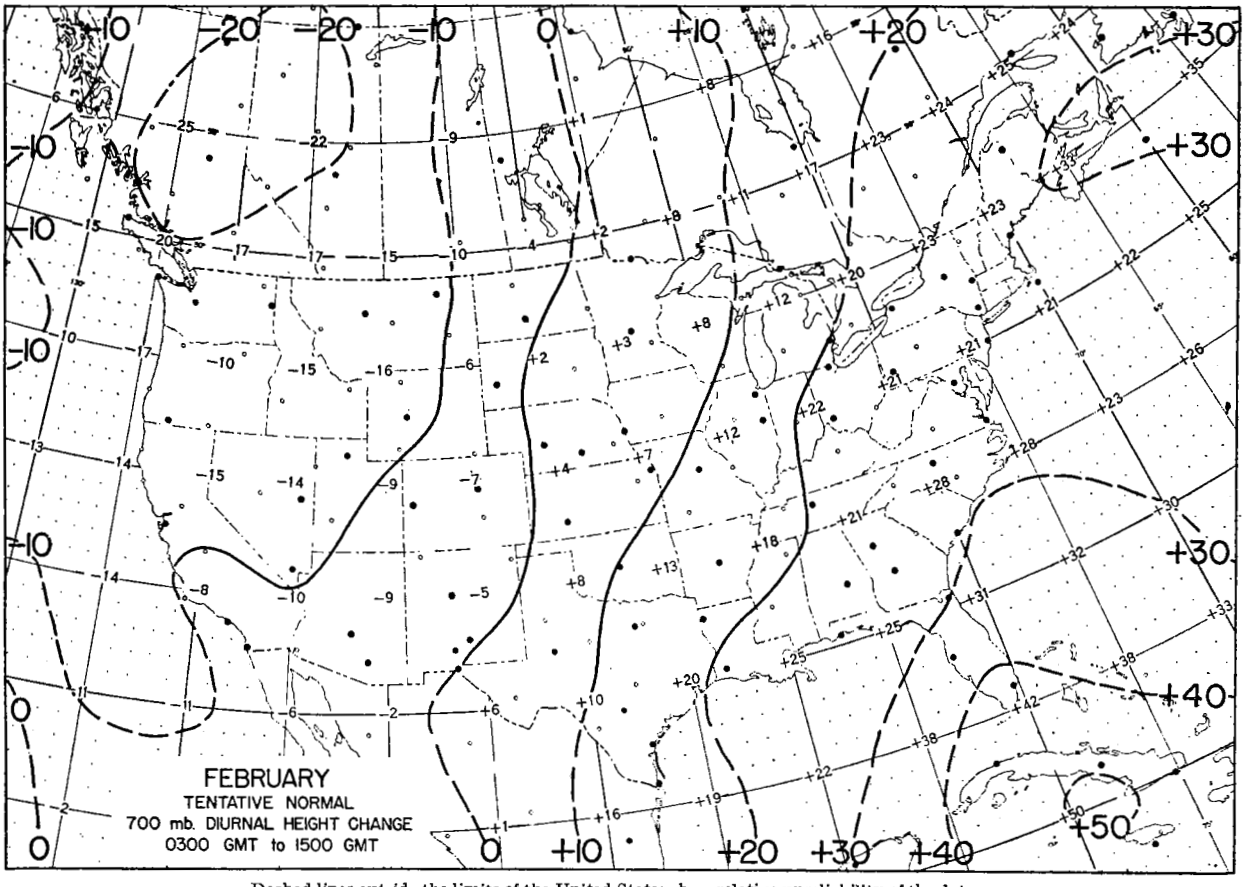
The graphical smoothing process used is equivalent to averaging monthly values for three consecutive months to get the normal value for the intermediate month by means of the smoothing formula; $b_n=\frac{a+2b+c}{4}$, where b_n is the normal being computed and a, b, and c are monthly mean values for the preceding, current and succeeding months, respectively. The process has the effect of increasing the length of the record. Monthly values of the diurnal variation taken from the smoothed curves are the tentative normals presented in the charts published here.

THE CHARTS OF TENTATIVE NORMALS

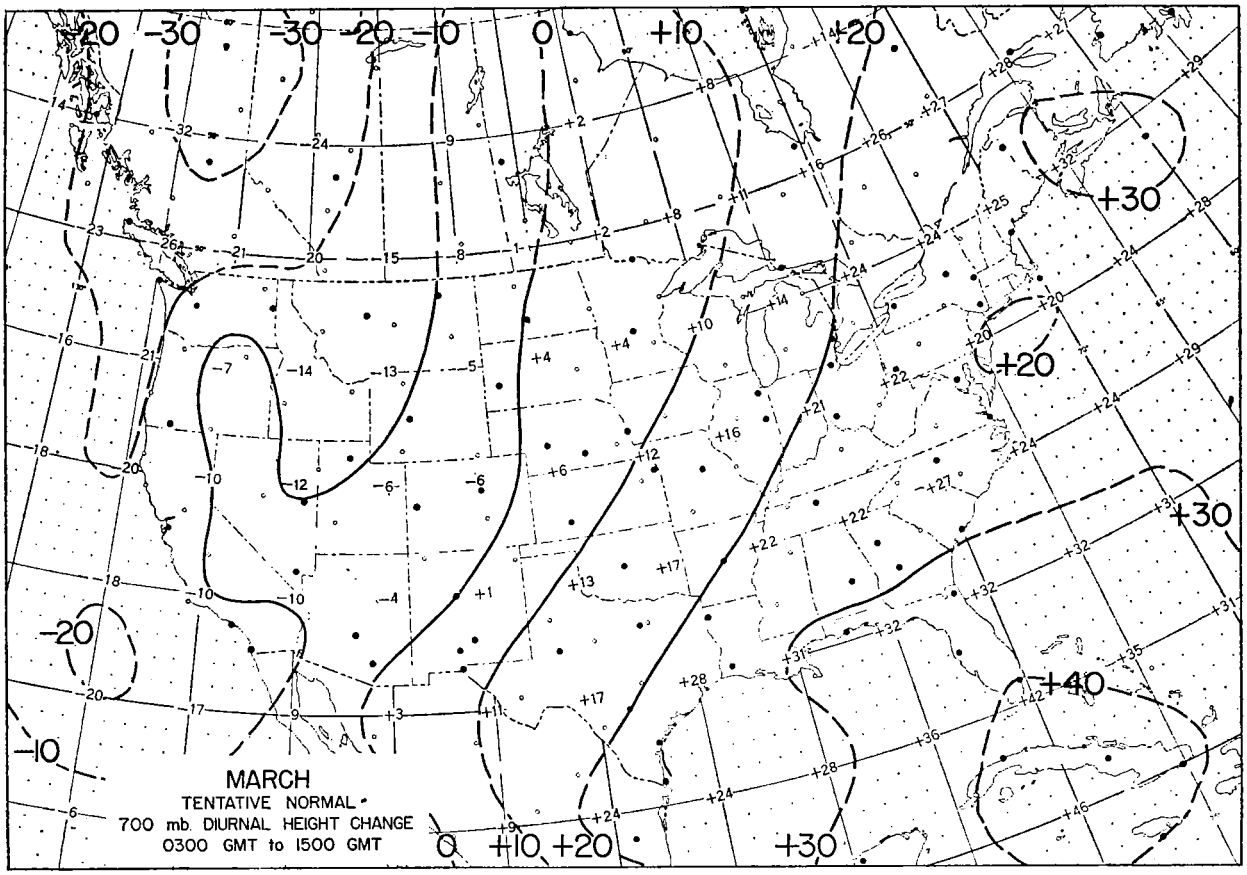
On the 12 monthly charts, there is plotted for each latitude-longitude intersection for which data were available, the tentative normal diurnal change in height of the 700-mb. surface from 0300 GMT to 1500 GMT. The units are feet per 12 hours. In addition, isopleths are drawn for 10-foot intervals. The dashed isopleths in areas outside the United States indicate less reliable values resulting from irregularity or sparsity of observations. The tentative normal diurnal height change from 1500 GMT to 0300 GMT can be taken from these charts by reversing the sign of the change.

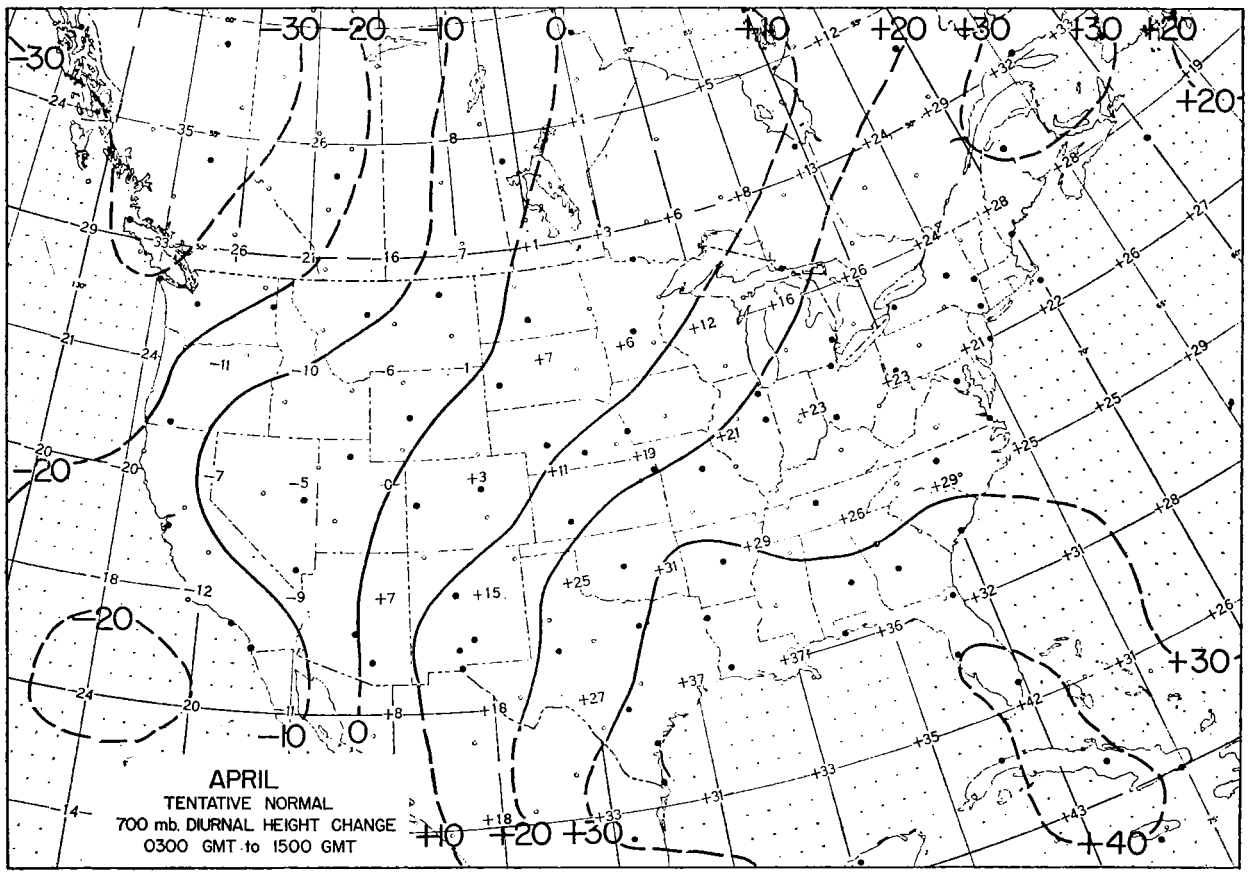
(Text continued on page 175)





Dashed lines outside the limits of the United States show relative unreliability of the data.
To obtain the normal change for the period 1500 GMT to 0300 GMT, simply reverse the sign.
Based on data for 1947 and 1948.





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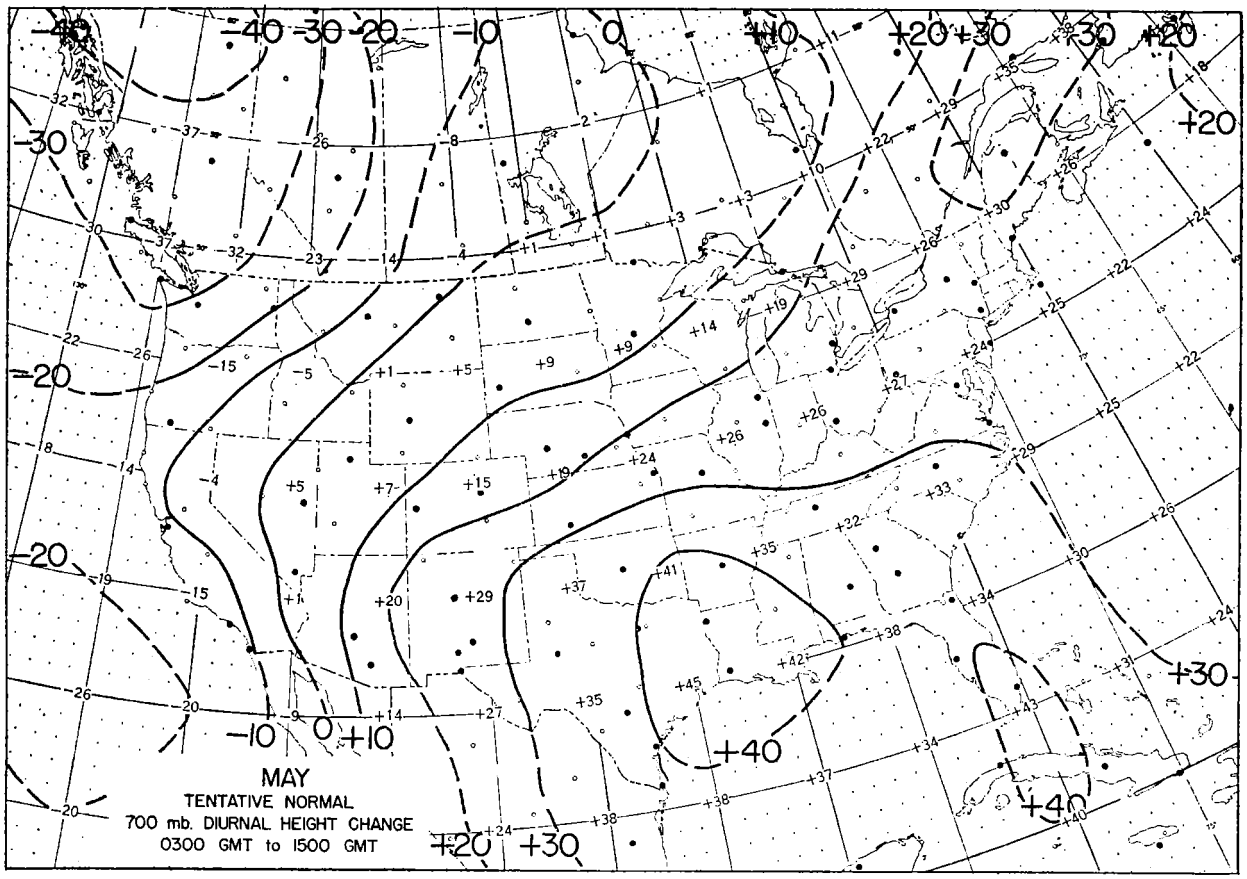
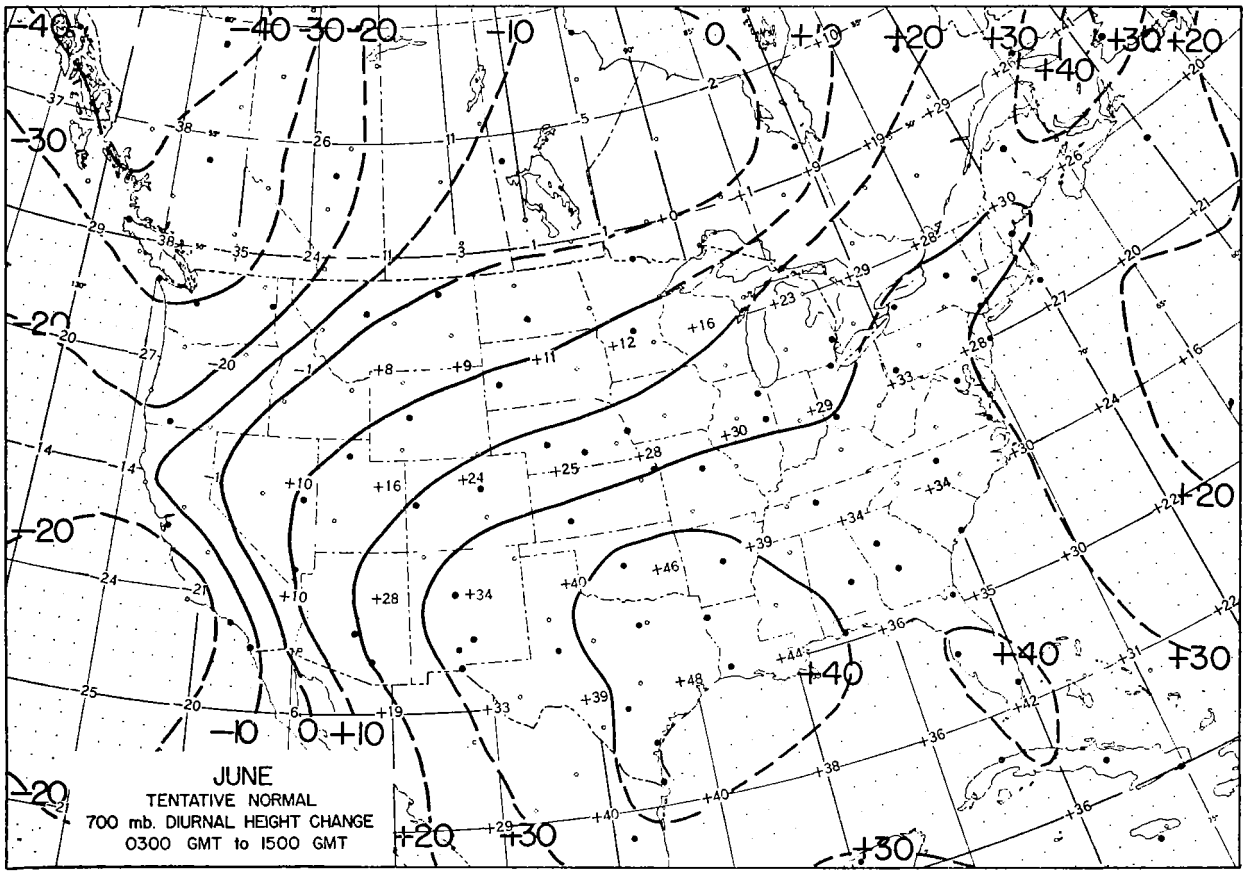
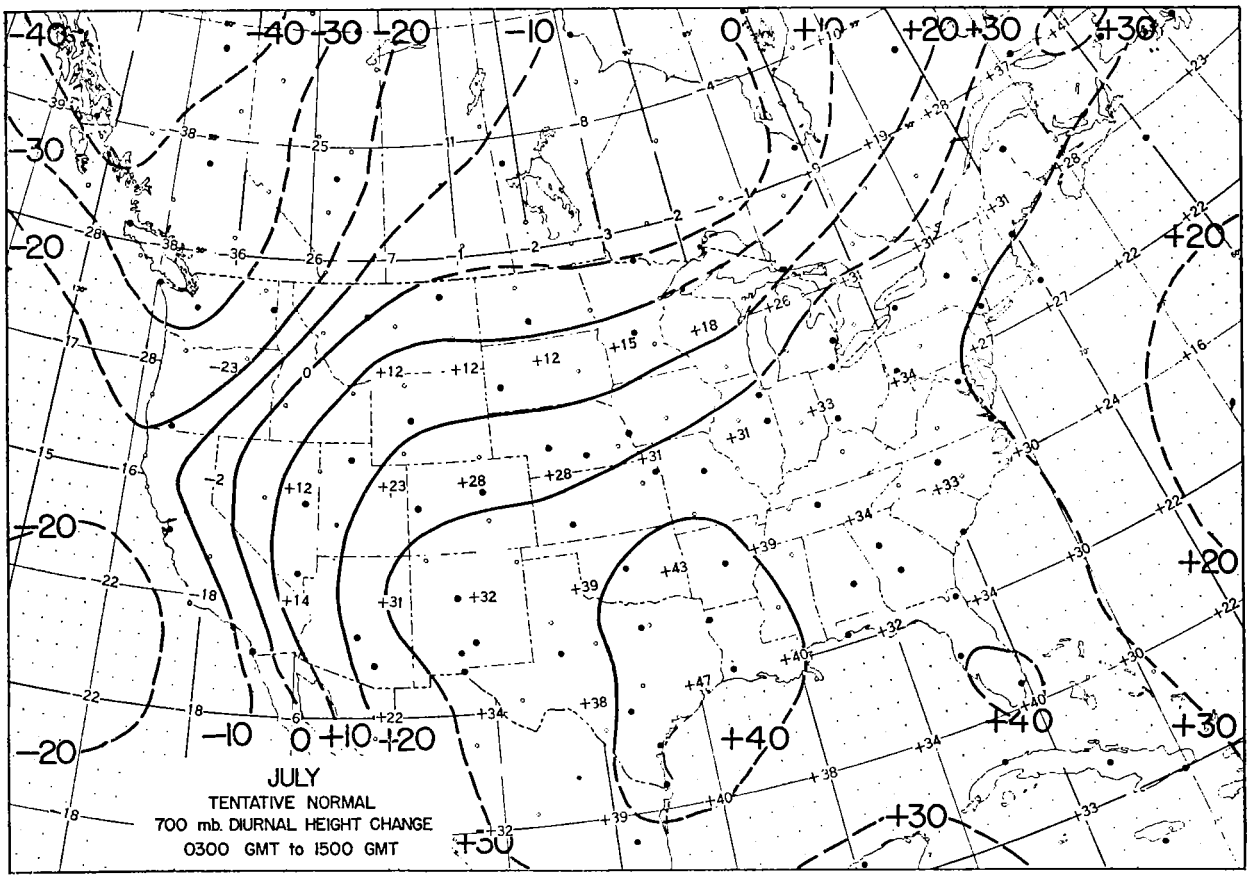
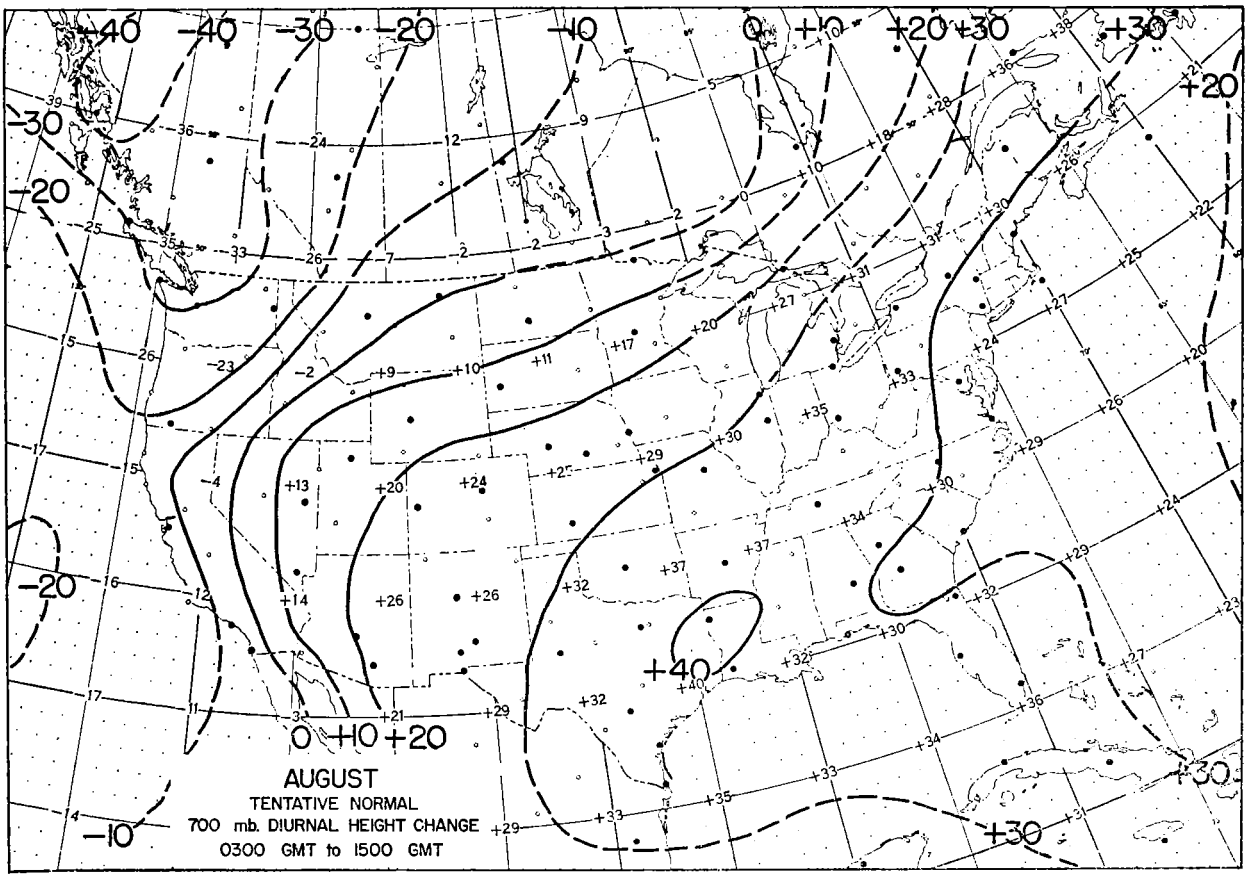


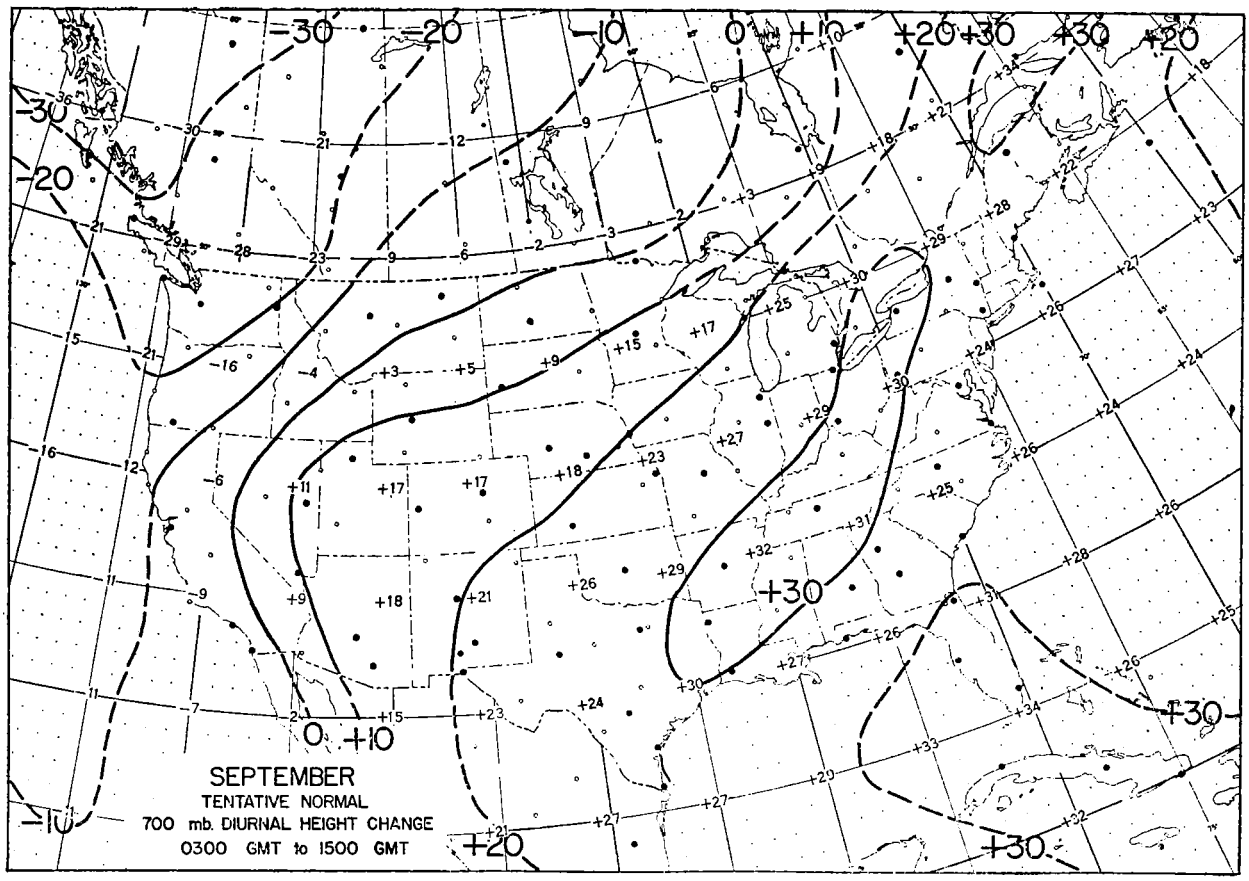


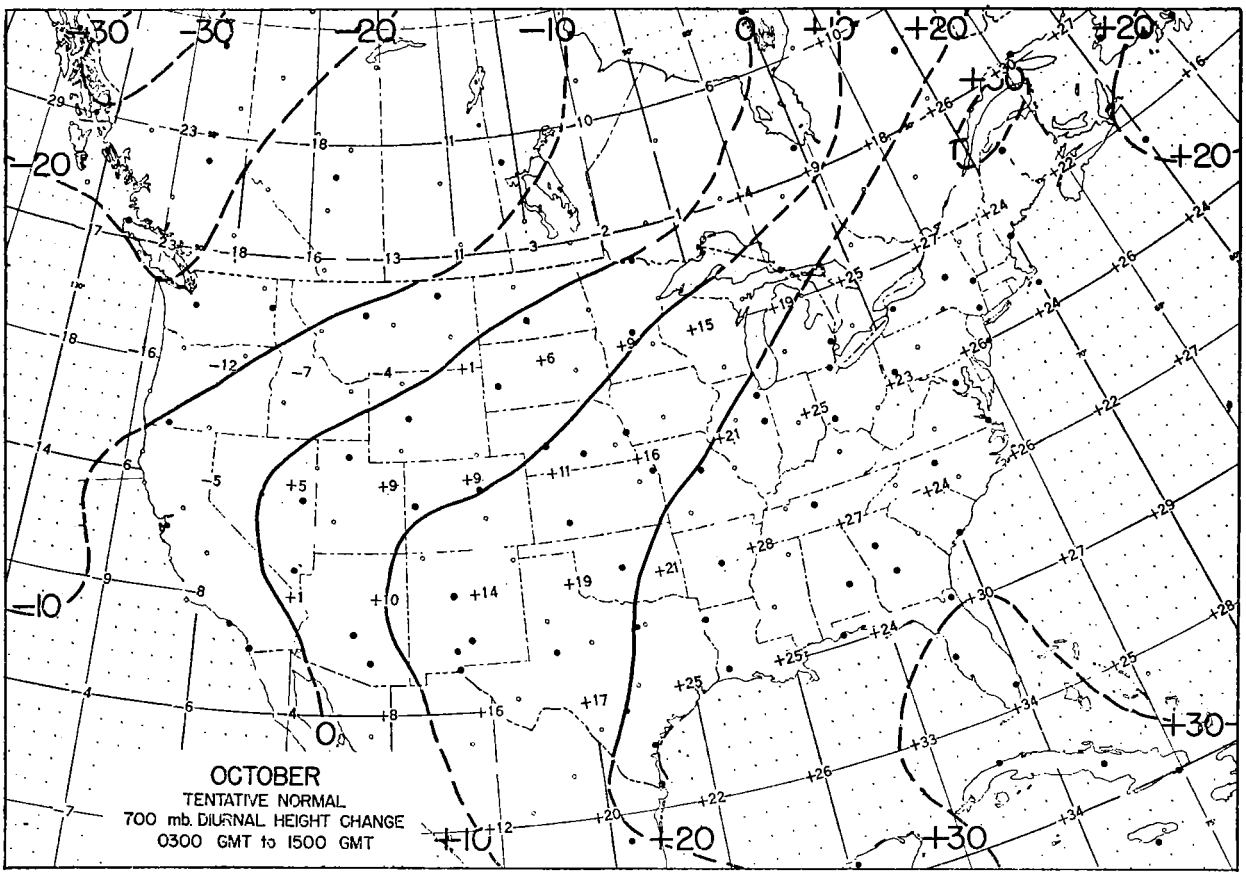
Dashed lines outside the limits of the United States show relative unreliability of the data. To obtain the normal change for the period 1500 GMT to 0300 GMT, simply reverse the sign. Based on data for 1947 and 1948.





Dashed lines outside the limits of the United States show relative unreliability of the data. To obtain the normal change for the period 1500 GMT to 0300 GMT, simply reverse the sign. Based on data for 1947 and 1948.





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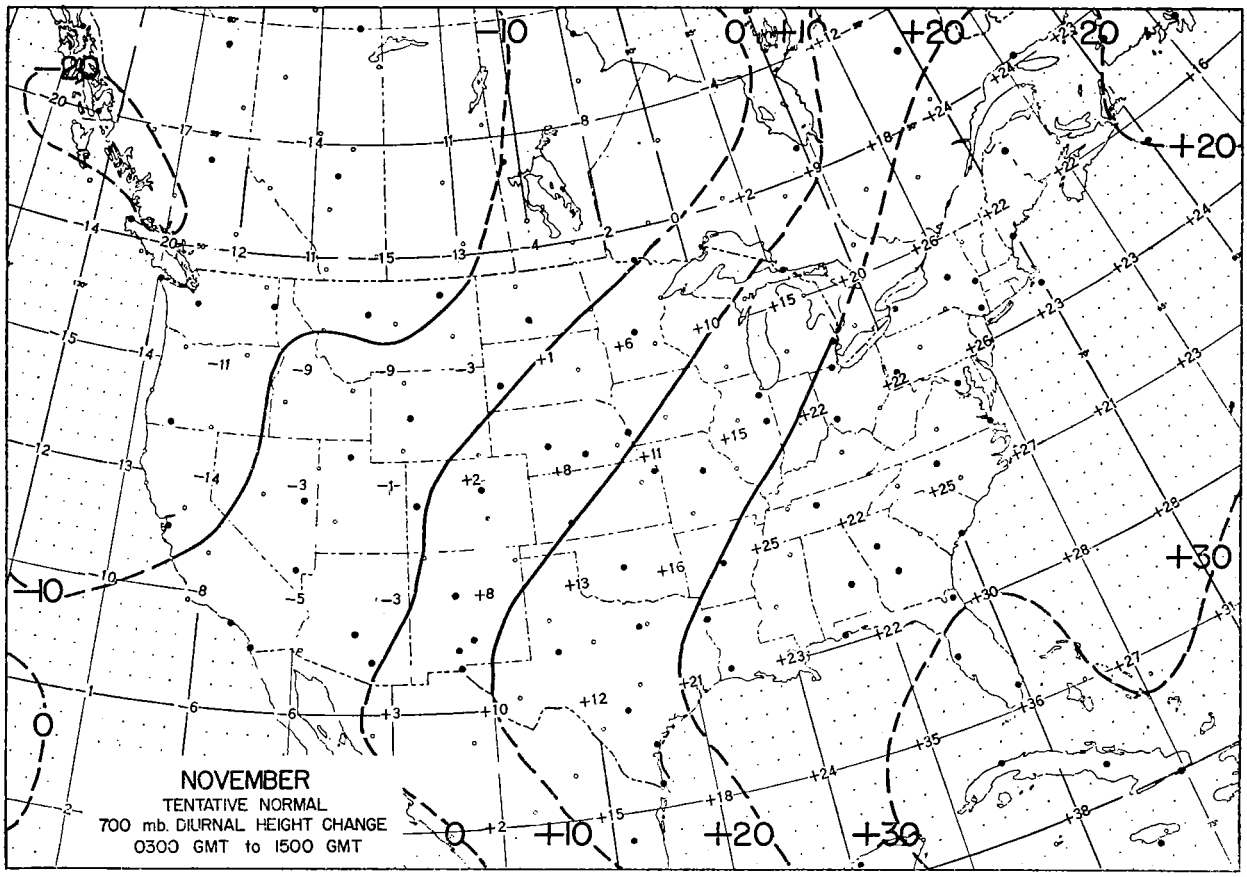

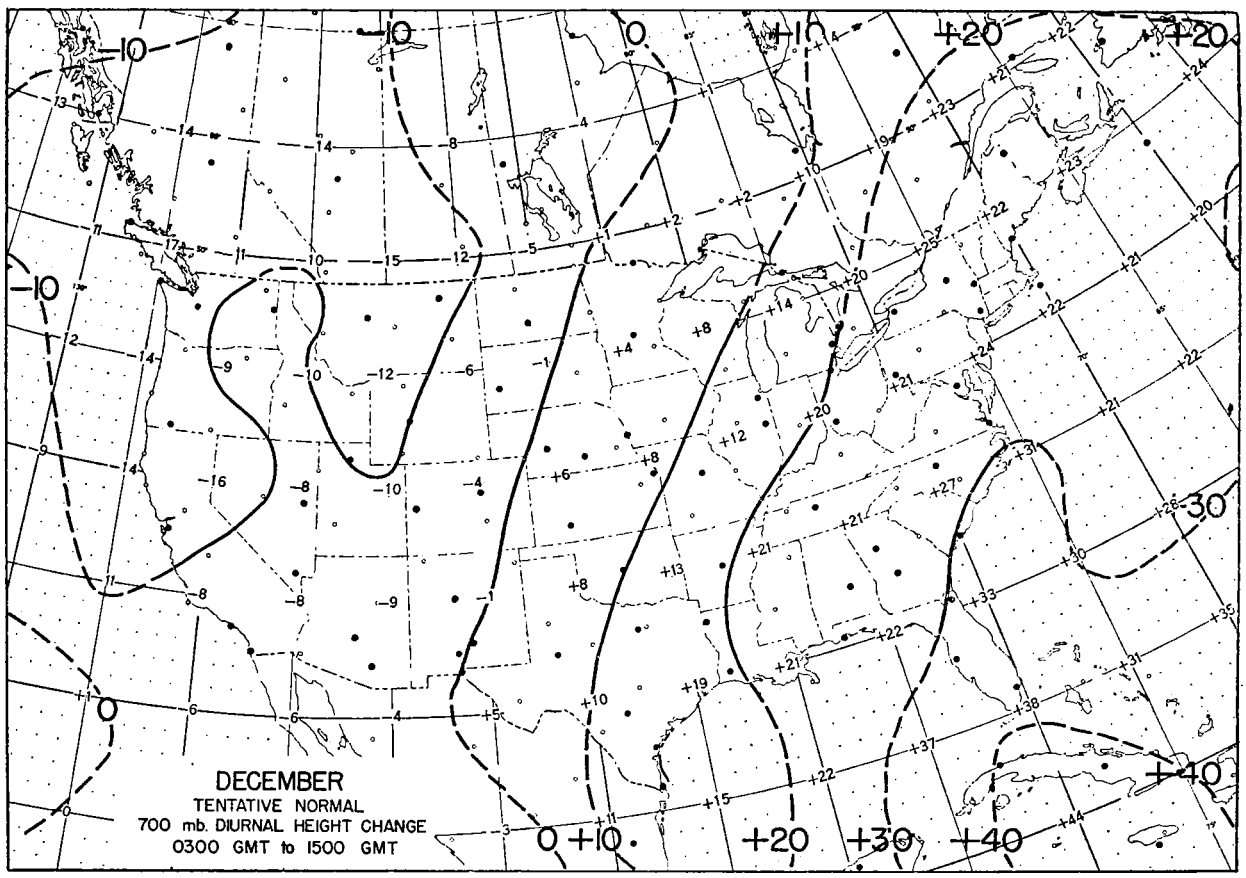

Dashed lines outside the limits of the United States show relative unreliability of the data. To obtain the normal change for the period 1500 GMT to 0300 GMT, simply reverse the sign. Based on data for 1947 and 1948.

RELIABILITY OF THE CHARTS

In the description of the computation of the tentative normals, factors affecting the reliability of the results and methods used to minimize these effects were discussed. Though the final results are considered to give good estimates of normals based on long period averages, it would be worthwhile for users of the charts to keep in mind these limitations.

The largest source of variability in the month to month values results from large magnitude height changes of the constant pressure surface as systems with strong contour gradients move rapidly across the map. This kind of variability would be eliminated by a climatological record of great length. Some of the diurnal values presented here may prove to be in error by as much as 10 feet per 12 hours. This estimate is based on the amount of smoothing of data that was necessary. A thoroughly reliable set of diurnal height change charts is impossible until there is available for all radiosonde stations a long-period record of observations made with instruments free of radiational temperature errors.

DEPARTURES FROM NORMAL

In addition to limitations resulting from the short period of record, departures from normal associated with anomalous weather conditions should be considered when the charts are used in synoptic work. The diurnal height change for any given day will differ from the normal value depending on fluctuations in cloudiness, humidity, and wind, and possibly with variations in solar radiation, thickness of the ozone layer, tidal effects, etc. The probable magnitude of the anomaly is suggested by variations in diurnal pressure tendencies at surface stations. Over inland areas, the surface diurnal pressure change will often double its normal value in an area temporarily under the influence of a high pressure center, especially if subsidence is pronounced, skies clear, and humidities very low. Large anomalies in the surface diurnal pressure change are associated with large anomalies in the diurnal temperature range. The anomaly is, then, largely a low level phenomenon and will become smaller with distance above the ground. At 700 millibars, the anomaly should be of greater significance over the higher ground of the western States. O. R. Wulf [2] has observed diurnal tendencies near the 300-mb. level to be larger than normal in the vicinity of a ridge and smaller in the vicinity of a trough. Further experience with the charts presented here should indicate the extent to which such relations hold at the 700-mb. level.

ACKNOWLEDGMENT

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